AEROLOGICAL OBSERVATIONS MADE WITH A CAPTIVE BALLOON FROM A MOVING SHIP

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Since 1908 regular daily or twice-daily observations of the pressure, temperature, and humidity of the upper air have been made over Lake Constance in the vicinity of Friedrichshafen [1] (lat. 47° 39′ N., long., 9° 29′ E.) in the extreme southern limit of Germany. The average daily height reached throughout the year is approximately 5 kilometers, while an extreme altitude of 7.8 kilometers has been attained.

The method consists in allowing a captive balloon to rise approximately vertically over a ship. The ship must be maneuvered to move through the water with a speed and direction equal to the horizontal component of the balloon's movement. In other words, the ship keeps pace with the balloon. On Lake Constance, where the wind force rarely exceeds force 5 (Beaufort scale), it is possible to take observations on 95 per cent of the days with the same balloon. Kites are employed on the remaining 5 per cent of the days when strong winds endanger the balloon. It would be possible to take observations in high winds if a faster ship were available.

The ship used is a kind of torpedo boat specially built in 1908 for the purpose, with coal-burning engines which develop a maximum speed of 16 knots. The ship has a beam and draft of 3.4 meters and 1.4 meters, respectively. The necessary personnel consists of four seamen and two meteorological observers.

The balloon employed is approximately spherical with a maximum diameter of 15 meters and a gas capacity of 80 cubic meters (2,850 cubic feet). The balloon fabric is of cotton with a rubber lining, having a total thickness of 1.5 millimeters. Balloons have lives varying between six months and two years, and cost, if bought ready made, about $500. The Friedrichshafen Observatory, however, purchases the rubberized cotton and makes up the balloon without difficulty for a total cost of $200. The balloon is ordinarily filled with hydrogen to two-thirds capacity. Every three weeks it is entirely emptied of gas and filled anew from cylinders. A cylinder of about 4 cubic meters hydrogen (145 cubic feet) is added every morning before the ascent to replace gas lost through diffusion of hydrogen through the fabric and leakage. The rate of diffusion of hydrogen through the fabric varies through wide limits despite the manufacturers' efforts to obtain impermeability and uniformity.

The recording apparatus employed is a Bosch meteorograph weighing about 1 kilogram and recording pressure, temperature, and humidity. The apparatus is protected from direct radiation by reflecting nickeled paper which lines the inside of the wicker container. The meteorograph basket is slung in a wooden cradle suspended about 8 meters below the filling mouth of the balloon. The registration is made on lightly-smoked millimeter-ruled oiled paper. The oiled paper protects the record against the effects of humidity while the cross-section ruling facilitates rapid reduction of observations.

Steel wire 0.7 millimeter in diameter with a breaking strain of 90 kilograms is used for attaching the balloon for the first 3,000 meters of its ascent. Subsequently finer wire (0.6 millimeter in diameter) may be employed. In spells of calms and light winds lighter wire has been found amply strong. About 10 kilometers of wire is kept on reels about 2 meters abaft the ship's funnel. From the reel the wire passes directly back through a pulley fastened to a stout support on the ship's deck directly above the rudder. A control mechanism allows the wire to be played out or drawn in at any velocity from 12 meters a minute to 420 meters a minute. The operator can read, on conveniently placed dials, the length of the wire run out and the tension on the wire. The velocity of the vertical air currents may be determined from the automatically recorded tension on the wire. The observers obtain the direction and velocity of the upper winds with the same accuracy as from pilot-balloon observations.

When the balloon subtends a vertical angle of less than 55°, on account of high wind velocity aloft, the registration is generally not sharp owing to the violent swaying to and fro of the meteorograph. On the other hand, the ship's officers endeavor to keep the vertical angle of the balloon less than 85° to prevent vertical movements of the balloon being transmitted directly to the wire reels.

No balloons have been lost through explosions, fire, or lightning, and on an average less than one balloon a year breaks away. The loss of material and cost of instrument repairs are very small.

The vertical velocity of the balloon, if free, would be about 330 meters a minute. Owing to the wire attachment, the balloon leaves the place of storage on the after deck of the ship with a vertical velocity from 240 to 300 meters a minute. When the velocity falls below 120 meters a minute, generally due to the increasing load of wire, there is not sufficient ventilation to overcome radiation effects in strong sunlight. As soon as the operator begins to draw the balloon back to the ship the necessary ventilation is immediately secured. The portions of the record falsified by insufficient ventilation are invariably so obvious that they may be promptly discarded from further computation on the rare occasions they occur. The difference in recorded temperatures between ascent and descent is of the order of 0.2° C.

The average duration of a flight to a height of 5 kilometers from the instant the meteorograph leaves the ship's deck to its return is about 45 minutes. The working out of the temperature, pressure, and humidity at 15 significant altitudes and coding the data for telegraphic transmission require about 40 minutes.

This method of using a captive balloon for carrying a meteorograph to heights of from 4 to 7 kilometers could probably be employed to great advantage in low latitudes where ballon-sondes would be lost very often in the sea. The method has advantage over kites in that it requires only about one-third the time for the same height of ascent. The meteorograph ordinarily receives little jolting so that much more sensitive instruments may be employed with a balloon than with a kite. As the records for both ascent and descent are equally distinct two independent determinations of temperature and humidity, taken within a short space of time, may be made at any desired altitude. This provides an invaluable check on computations and a lag and other instrumental defects.

A captive balloon can be sent up in foggy and hazy days when airplane flights would be dangerous, especially

[1] Count Zeppelin, in the course of his airship investigations, established, about 1900, the meteorological station at Friedrichshafen. Dr. H. Hergesell, collaborating with Count Zeppelin from 1900 to 1908, made use of both captive balloons and captive kites, fastened to a moving ship for taking upper-air observations. Dr. E. Kleinschmidt, who was appointed director of the Drachenstation in 1906, introduced during his term of office certain practical details in the captive-balloon method here described.

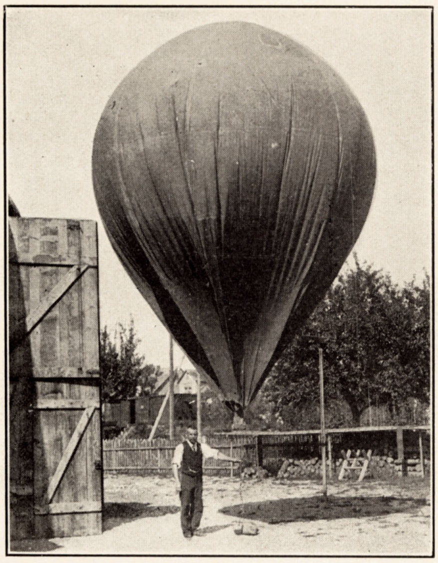

FIGURE 1.—Balloon inflated to hold about 2,000 cubic feet of hydrogen

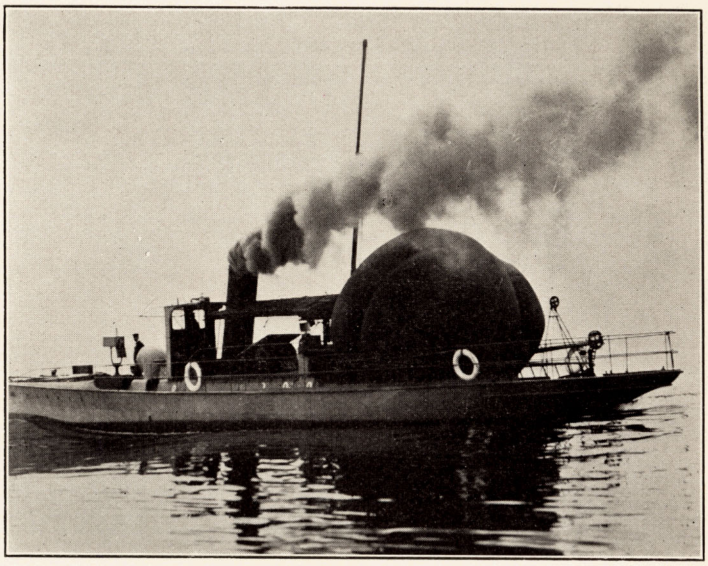

FIGURE 2.—Balloon stowed on after deck of torpedo boat *Gna*

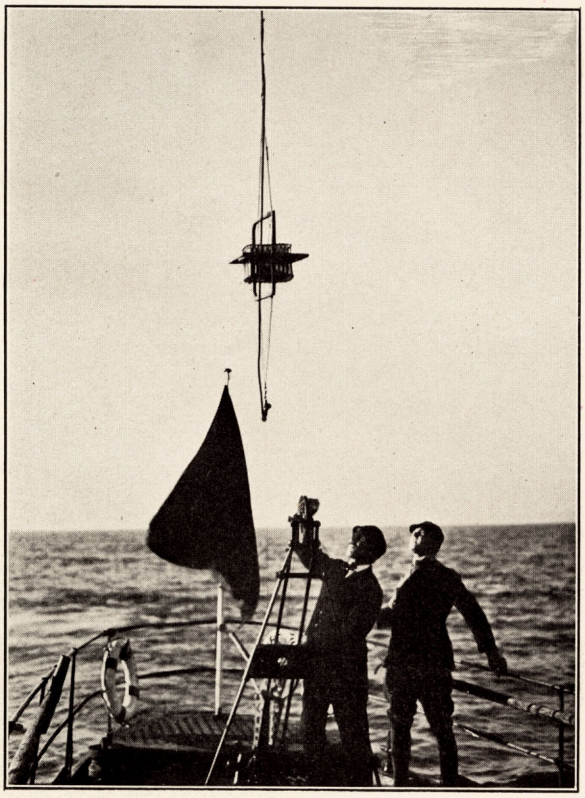

FIGURE 3.—Balloon just after leaving ship

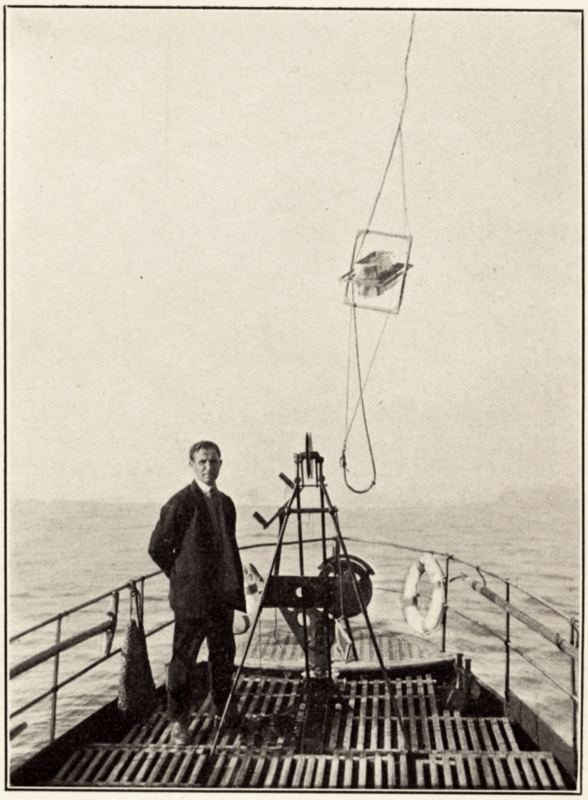

FIGURE 4.—Mechanism for playing out mooring wire, and cradle for meteorograph

at a coastal station. The method can not be used successfully in regions with high winds or where harbors are icebound for a considerable portion of the year. However, meteorologists, with the cooperation of port or naval authorities might obtain by the captive-balloon method here described, extremely valuable data concerning the temperature and humidity of the upper air in tropic and tradewind regions. Only very meager aerological observations are now available from this vast area.

The writer is greatly indebted to Dr. W. Peppler, director Drachenstation, Friedrichshafen, for opportunity to take part in the daily program of balloon ascents over Lake Constance and for many details of the method given in this article.

No detailed description of the technique and apparatus employed in taking aerological observations with a captive balloon, moored to a moving ship, has yet been published.

Brief notices regarding the method have appeared in Beiträge zur Physik der freien Atmos., Band I, page 1, et seq., and in the MONTHLY WEATHER REVIEW for September, 1908, volume 36, page 284, by E. Kleinschmidt (translation by C. F. Talman). Doctor Kleinschmidt has given a fuller account in the Deutsches Met. Jahrbuch, 1908. Capt. G. Hugo presented a report on the method to the Premier Congrès International de la Sécurité aérienne in Paris, 1930, which will appear in the Proceedings of the Congress.

METEOROLOGY AND SEASONAL WEATHER FORECASTING: ANNUAL PROGRESS REPORT OF THE SCRIPPS INSTITUTION OF OCEANOGRAPHY

By GEO. F. MCEWEN, Physical Oceanographer, and A. F. GORTON, Associate in Meteorology

[La Jolla, Calif., January 1931]

Our efforts during the past year were devoted to a further study of the relation between seasonal rainfall in California and quarterly values of temperatures and pressures in various parts of the world, and to an analysis of cycles in rainfall and run-off by statistical methods, in particular, Streiff's method of successive integration. Correlation coefficients higher than 60 per cent have been established for several indices covering the period 1916–1930, these including La Jolla water temperatures during the upwelling period and July to September, also, Tokyo air temperatures versus Hetch-Hetchy district rainfall and Huntington Lake inflow. The Tokyo index prior to 1916, shows a lower degree of correlation. Other indices, such as August to October rainfall in southern Alaska (with respect to following winter's rain in California) proved disappointing.

Air temperatures, in general, are poor indicators of California precipitation. Groissmayr's correlation between summer conditions in India and following winter temperature departures in central Canada was found to be without much bearing on rainfall in this state, neither was there much connection between winter temperatures in Canada and California. There is some evidence that Scripps Pier temperatures during the upwelling period indicate the trend of temperature departures in southern California during the fall.

A composite index has been worked out which is found to fit rainfall departures in southern California much more exactly than the original McEwen index. This takes into account the rapidity with which the temperature approaches a maximum and the time of occurrence of the maximum temperature, as well as the actual magnitude of the latter. The same procedure applied to the Pacific Grove temperatures gives a good indication of rainfall departures in the north coast region.

As to cycles, the important ones are in order of length, the secular cycle of 50 to 60 years, the Brückner cycle of 22 to 26 years, the double-Wolf cycle of 5 to 6 years, and the Clough cycle of 2 to 3 years. The 5 to 6 year cycle seems to be the most important for forecasting purposes. The Brückner cycle is prominent in the rainfall of Southern California and is found in records of lake levels (Great Salt Lake and the Great Lakes). The next maximum in the 5 to 6 year cycle will come probably in 1933, and a rise in the Brückner cycle now under way, will bring rainfall to a maximum around 1938–40.

The annual forecast was published October 15, 1929, in various newspapers of the State and was distributed through the Associated Press to newspapers outside the State; the same forecast appeared in the Bulletin of the American Meteorological Society and the California Citrograph. A paper prepared by Doctor Gorton on the results of the last two years' work was published in the Electrical West (September, 1930) and much the same material was presented at a meeting of the American Institute of Electrical Engineers in Portland, Oreg., September 5 (published in Journal, A. I. E. E. December, 1930). Doctor McEwen prepared a paper entitled "Our Rainfall: How is it Formed and What Becomes of It?" (published in the Scientific Monthly, November, 1930).

During the coming year we plan to devote our time to the following studies:

a. A further analysis of factors affecting seasonal storm tracks.

b. Surface temperatures off the California coast by 1° squares between latitude 30° and 40°, for period 1900–1930. Data from United States Weather Bureau.

c. Gulf Stream temperatures and their relation to seasonal rainfall in California. (Data by Brooks.)

d. Further study of cycles in rainfall, run-off, sun spots, tree rings, etc.